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Method for operating the drive train of a motor vehicle

The invention relates to a method for operating the drive train of a motor vehicle according to the preamble of patent claim 1.

DE 42 30 989 A1 discloses a method for operating a drive train with a prime mover in the form of an engine, with a manual shift transmission and with a power divider which is not power-shiftable and which is actuated by external force. A clutch actuated by foot force is arranged between the prime mover and the manual shift transmission. The power divider is arranged downstream of the manual shift transmission and has actuating members, by means of which shifts in the form of a change from road travel to cross-country travel with a high step-up ratio can be executed. The actuating members of the power divider are activated by a control device in the form of central control electronics.

In order to execute a shift, a vehicle driver has to trigger a shift requirement by opening the clutch and actuating a switch in the form of a preselection switch in the interior of the motor vehicle. This shift requirement is then implemented by a control device.

The object of the invention is, in this respect, to propose a method for operating a motor vehicle, by means of which it becomes possible to operate the motor vehicle comfortably. The object is achieved, according to the invention by means of a method as claimed in claim 1.

According to the invention, in the presence of a shift requirement for the power divider, before the

commencement of the shift a torque of the shifting members involved in the shift is reduced automatically by a control device. The shift requirement may be a requirement for a change of a step-up ratio of the power divider or a changeover between two-wheel and four-wheel drive. This shift requirement may be triggered by the vehicle driver, for example by the actuation of a switch in the interior. Alternatively to this, the requirement may be generated by a control device as a function of operating variables of the motor vehicle and of environmental variables.

The reduction of the torque of the shifting members, for example gearwheels, sliding sleeve and/or synchronizing bodies, is necessary, since a shift, in particular a deselection of the shifted gear, is possible in non-power-shift transmissions only when no torque or only a very low torque is transferred by the shifting members which are in engagement.

The reduction can take place by means of the controlled setting of the output torque of the prime mover, for example to zero, or by separating the connection between the prime mover and the power divider.

After the reduction in the torque has taken place, the shift is carried out by means of the suitable activation of activating members with actuation by external force, that is to say without the assistance of the vehicle driver. The actuating members may be designed, for example, as electric motors or hydraulic or pneumatic piston/cylinder units. After the conclusion of the shift, the control device again permits a torque at the shifting members. For this purpose, the output torque of the prime mover is set again according to an instruction from the vehicle driver or the connection between the prime mover and power divider is restored. The instruction from the

vehicle driver is derived from a degree of actuation of a power actuating member, for example a position of an accelerator pedal.

The transmission may in this context be designed as a manual shift transmission or an automated transmission.

When the method according to the invention is employed, no actuation of a clutch by the vehicle driver is necessary in order to execute a shift of the power divider. Should the driver wish to execute a shift, he merely has to trigger a shift requirement. The operation of the motor vehicle consequently becomes simpler and more comfortable for the vehicle driver.

In addition, by virtue of the method according to the invention, it is possible that the control device can decide whether a shift is appropriate and trigger this and carry it out without actions by the vehicle driver.

In an embodiment of the invention, the transmission is designed as an automatic transmission. In order to reduce the torque of the shifting members, the control device interrupts, by the opening of a clutch, a force flux between prime mover and power divider which is produced by means of a positive or frictional connection. In particular, the control device opens a clutch in the automatic transmission, clutch also being understood as meaning a break in the automatic transmission. To open the clutch, the control device activates actuating members of the automatic transmission in a suitable form. Alternatively to a clutch in the automatic transmission, for example when an automated gearwheel change transmission is employed, a starting clutch arranged between the prime mover and the automatic transmission may also be opened. As a result of the opening of the clutch, the power divider is no longer connected to the prime mover, so that the

drive train is separated and is consequently free of torque.

After the conclusion of the shift, the control device restores the force flux by closing said clutch.

The automatic transmission may be designed, for example, as an epicyclic transmission, continuously variable transmission, double clutch transmission or automated gearwheel change transmission. The motor vehicle may have in each case for the prime mover, the automatic transmission and the power divider a separate control device or control devices for simultaneously more than one of the assemblies mentioned.

Consequently, the torque of the shifting members can be reduced with a high degree of liability and it becomes possible to shift the power divider in a reliable way. Particularly in the case of distortions in the drive train, such as may occur, for example, on cross-country trips, the reduction in the torque of the shifting members by influencing the output torque of the prime mover is highly unreliable.

In an embodiment of the invention, during the shift of the power divider, the control device automatically reduces the output torque of the prime mover. The instruction from the vehicle driver by the power actuating member is in this case ignored. After the conclusion of the shift, the control device again permits an increase in the output torque, and the instruction from the vehicle driver is implemented again. The decrease and increase in the torque may take place, for example, along ramps.

Consequently, the vehicle driver can continue to actuate the power actuating member during a shift of the power divider, without the rotational speed of the

prime mover, with the drive train open, rising in an unwanted way and unnecessarily. During the closing of the clutch, the risen rotational speed would in most instances have to be reduced again. The operation of the motor vehicle consequently becomes simpler and more comfortable.

In an embodiment of the invention, the motor vehicle has an activatable brake system which may be designed, for example, as an electrohydraulic brake system. By means of the brake system, a braking torque can be applied to the motor vehicle, independently of a position of a brake pedal, as a result of the activation of actuating members by a control device.

The control device of the power divider monitors the speed of the motor vehicle and/or variables derived from this during a shift of the power divider. Derived variables are, for example, a difference between a current speed and a speed of the commencement of the shift, an acceleration of the motor vehicle or a direction of travel.

As a function of the result of the monitoring, the control device activates the brake system at least indirectly. Activation takes place, for example, in that the control device sends a requirement for a braking torque to the control device of the brake system, this control device then implementing the requirement. After the conclusion of the shift, any requirement is canceled and therefore any braking torque which is possibly present is reduced.

The shift of the power divider may take up a few seconds, for example up to three seconds. During this time, the driver train is separated, that is to say the prime mover is not connected to the driven vehicle wheels, so that no torque from the prime mover can act

on the vehicle wheels. During this time, unwanted and uncontrolled movements of the motor vehicle may occur, for example when the motor vehicle is operated on a slope. By the speed of the motor vehicle and any activation of the brake system being monitored, active influence can be exerted on the movement of the motor vehicle in spite of the open drive train. Consequently, an especially reliable operation of the motor vehicle is ensured, and uncontrolled operation of the motor vehicle is prevented.

In the embodiment of the invention, the control device activates the brake system when a false direction of travel is detected. A false direction of travel is present when the current direction of travel is opposite to the direction of travel desired by the vehicle driver. This may be determined, for example, from the comparison of the current direction of travel with a position of the selector lever of the automatic transmission or with the direction of travel of the commencement of the shift. The current direction of travel may be determined by means of suitable rotational speed sensors on the vehicle wheels. The control device activates the brake system, in particular, to the standstill of the motor vehicle and subsequently holds the motor vehicle up to the conclusion of the shift. In this case, when the motor vehicle is subsequently started, a rolling opposite to the desired direction of travel can likewise be prevented. The function of what is known as a hill holder can thereby be implemented.

A false direction of travel may occur, for example, in the event of a shift of the power divider when the motor vehicle is driving up a steep slope at low speed. During this shift, the driver train is separated, and no drive torque from the prime mover acts on the motor vehicle. Due to the slope downforce, the motor vehicle

is decelerated and, in the most unfavorable case, is accelerated opposite to the original direction of travel. The motor vehicle could move toward motor vehicles which may possibly be following it. By the brake system being activated, the unwanted movement can be prevented, and therefore safety-critical situations can be ruled out. This makes it possible to operate the motor vehicle particularly reliably.

In an embodiment of the invention, the control device activates the brake system if a difference of the current speed from an initial speed at the commencement of the shift and/or a speed gradient overshoot limit values. In particular, by means of a suitable braking torque, a constant differential speed or a constant speed gradient, that is to say a constant acceleration, can be set.

This prevents the situation where the speed of the motor vehicle increases too sharply during a shift of the power divider. This situation may arise, for example, in the event of a shift when the motor vehicle is driving down a steep slope, since, with the drive train separated, there is also no engine braking action on the motor vehicle. The separation of the drive train may therefore lead to a sudden very sharp acceleration of the motor vehicle. This acceleration may be very surprising to the vehicle driver, and this may therefore lead to a safety-critical driving situation. By the brake system being activated when one of the conditions mentioned is fulfilled, the safety-critical driving situations described cannot arise, thus resulting in a particularly reliable operation of the motor vehicle.

In an embodiment of the invention, in the presence of a shift requirement, the control device calculates from the current speed of the motor vehicle and the step-up

ratios in the drive train after the shift a rotational speed of the prime mover which occurs after the shift. This is relevant only when the step-up ratio of the power divider changes during the shift. A shift is carried out in the automatic transmission or the shift requirement is suppressed as a function of the calculated rotational speed.

The control device determines, in particular, a permitted range of the rotational speed of the prime mover after the shift. The range may be stored, for example, in the control device or be determined as a function of operating variables of the motor vehicle, such as, for example, the speed, and/or environmental variables, such as, for example, the slope of the road. If the rotational speed can be brought into said range by means of a simultaneous shift of the automatic transmission, the shift of the automatic transmission and of the power divider is carried out. Very high step-up ratio jumps, for example of 2.6, may lie between step-up ratios of power dividers. This may correspond approximately to a shift from 2nd to 5th gear, for example, in the case of a 7-gear epicyclic transmission. Consequently, in the event of a shift in the power divider and a step-up ratio of the automatic transmission which remains the same, the rotational speed of the prime mover changes very sharply and may consequently lie very quickly outside the permitted range. This sharp change in rotational speed can be counteracted by a simultaneous change in the step-up ratio of the automatic transmission. To stay with the example mentioned, in the event of the shift of the power divider into a cross-country gear, that is to say into a lower step-up ratio, the step-up ratio jump of 2.6, the rotational speed of the prime mover can be kept virtually constant by means of a simultaneous shift of the automatic transmission from 2nd to 5th gear.

If, even as a result of a simultaneous shift of the automatic transmission, the rotational speed of the prime mover would lie outside the permitted range after the shift, the shift of the power divider is suppressed.

A large proportion of required shifts of the power divider can consequently also be executed. At the same time, however, the situation is prevented where the prime mover is in an unpermitted operating state after the shift, for example the rotational speed is too low or too high.

Further embodiments of the invention may be gathered from the description of the drawing. Exemplary embodiments of the invention are illustrated in simplified form in the drawing and are explained in more detail in the following description.

In the drawing:

fig. 1 shows a detail of a drive train of a motor vehicle with a power divider, and

fig. 2 shows a flowchart of a method for operating the motor vehicle in the event of a shift of the power divider.

According to fig. 1, a drive train 10 of a motor vehicle, not illustrated, has an internal combustion engine 11 which is activated by a control device 12. For this purpose, the control device 12 is signal-connected to actuating members, not illustrated, such as, for example, a throttle valve adjuster, and sensors, such as, for example, rotational speed sensors. Moreover, the control device 12 is signal-connected to a power actuating member 13 which is designed as an accelerator pedal and by means of

which a vehicle driver can set an output torque of the internal combustion engine 11. The control device 12 can calculate from detected variables further operating variables of the internal combustion engine 11, for example the output torque of the internal combustion engine 11.

The internal combustion engine 11 is connected via a shaft 14 to an automatic transmission 15 which is designed as a 7-gear automatic epicyclic transmission and which is activated by a control device 16. For this purpose, the control device 16 is signal-connected to actuating members, not illustrated, such as, for example, electromagnetic valves for the actuation of clutches and brakes, and sensors, such as, for example, rotational speed sensors. Moreover, the control device 16 is signal-connected to a selector lever 17, by means of which the vehicle driver can set a driving step of the automatic transmission 15, for example "D" for forward drive, "N" for a neutral position or "R" for reverse drive.

In the automatic transmission 15, a clutch 18 is illustrated, which represents a plurality of clutches and brakes in the automatic transmission 15. Said clutches and brakes act on elements of planet sets, such as a sun, web and ring wheel. A block 19 represents a plurality of planet sets, by means of which the various step-up ratios of the automatic transmission 15 can be implemented. Said clutches and brakes serve for setting the step-up ratios. As a result of the opening of the clutch 18 or even of more than one clutch or brake, the control device 16 can separate the force flux in the automatic transmission 15.

Downstream of the automatic transmission 15 is arranged a power divider 20 which is likewise activated by the

control device 16. The power divider 20 has two different step-up ratios via a road gear and cross-country gear. Moreover, a changeover can be made in the power divider between two-wheel and four-wheel drive. For this purpose, the power divider 20 has actuating members, not illustrated, which are activated by the control device 16. In addition, the control device 16 is signal-connected to an operating unit 21, by means of which the vehicle driver can trigger shift requirements for the power divider 20, for example a changeover from the road gear to the cross-country gear.

Two loose wheels 23 and 24 having a different diameter are arranged rotatably on an input shaft 22 of the power divider 20. In each case a loose wheel 23, 24 can be connected fixedly in terms of rotation to the input shaft 22 by means of a synchronizing body 25 and a sliding sleeve 26 which are arranged fixedly in terms of rotation on the input shaft. For this purpose, the sliding sleeve 26 can be displaced in the axial direction of the input shaft 22 by means of an actuating member, not illustrated. The loose wheels 23 and 24 mesh with associated fixed wheels 28 and 29 arranged fixedly in terms of rotation on an intermediate shaft 27. The fixed wheel 28 meshes with a fixed wheel 31 arranged fixedly in terms of rotation on an output shaft 30. The road gear is set by the loose wheel 23 being connected to the input shaft 22 and the cross-country gear with a higher step-up ratio is set by the loose wheel 24 being connected to the input shaft 22.

The output shaft 30 is connected by means of a rear drive shaft 32 to a rear-axle transmission 33 which in a known way transfers the output torque of the internal combustion engine 11 to rear vehicle wheels 35 via rear side shafts 34.

Arranged on the output shaft 30 of the power divider 20 is a shifting device 36, by means of which the output shaft 30 can be coupled to a front drive shaft 37. The output shaft 30 can consequently be connected to a front-axle transmission 38 which in a known way can transfer the output torque of the internal combustion engine 11 to front vehicle wheels 40 via front side shafts 39.

The shifting device 36 can be actuated by means of an actuating member, not illustrated.

Consequently, by means of the shifting device 36, a changeover can be made between two-wheel and four-wheel drive by the control drive 16.

Braking devices 41 which are activated by a control device 42 are arranged on the vehicle wheels 35, 40. For the sake of clarity, only one signal line 43 is illustrated. The braking devices 41 are designed electrohydraulically, the necessary hydraulic lines not being illustrated. The control device 42 is signal-connected to a brake pedal 44, by means of which the vehicle driver can set the braking torque applied by the braking devices 41 and consequently acting on the motor vehicle. For this purpose, the position of the brake pedal 44 is detected by means of a sensor, not illustrated, and is transfered to the control device 42 which then activates the braking devices 41 correspondingly. However, the control device 42 may also activate the braking devices 41 independently of the position of the brake pedal 44, for example at the requirement of the control device 16. The motor vehicle consequently has a brake system 45 which comprises at least the braking devices 41, the control device 42 and the brake pedal 44.

Integrated in the braking devices 41 are rotational speed sensors, not illustrated, by means of which the control device 42 can detect a rotational speed and a direction of rotation (forward or backward) of the vehicle wheels 35, 40. The speed and acceleration of the motor vehicle can be determined from these rotational speeds.

The control devices 12, 16 and 42 are signal-connected to one another via a seriel bus connection, for example via a CAN bus. Consequently, detected variables, such as, for example, rotational speed and direction of rotation of the vehicle wheels 35 and 40, can be exchanged, or requirements can be sent to a control device, for example the setting of a specific braking torque can be sent by the control device 16 of the automatic transmission 15 and of the power divider 20 to the control device 42 of the braking devices 41. The braking devices 41 are in this case activated at least indirectly by the control device 16.

The power divider may also be integrated into the automatic transmission.

The power divider may also additionally have a longitudinal differential.

Fig. 2 illustrates a flow chart of a method for operating the motor vehicle in the event of a shift of the power divider 20. The method is processed by the control device 16. The method commences in block 50 with a requirement for a shift, for example from road gear to cross-country gear.

In the following block 51, by means of the current speed and step-up ratios in the drive train 10, the rotational speed of the prime mover 11, established without any shift in the automatic transmission 15, is

determined in the gear to be selected. To increase the accuracy of the calculation, the speed of the motor vehicle of the conclusion of the shift may be precalculated from a stored duration of the shift, the current speed, the current acceleration and known driving resistances caused, for example, by a rolling resistance or a slope.

The following interrogation block 52 checks whether the required shift can be carried out. For this purpose, a check is first carried out as to whether the rotational speed calculated in block 51 lies within a permitted range. In a method which is not illustrated, the permitted range is likewise determined by the control device 16 as a function of operating variables of the motor vehicle and environmental variables. If said rotational speed lies outside the permitted range, a check is made, in a second step, as to whether the rotational speed of the prime mover 11 can be brought into the permitted range by means of a corresponding shift of the automatic transmission 15. Hence, for example in the case of a shift to cross-country gear, by means of an upshift of the automatic transmission 15 from 2nd to 4th gear.

If the result of the check is negative, the required shift cannot be executed, and therefore the requirement is suppressed and the method is terminated in block 61.

If the check in interrogation block 52 has a positive result, the method is continued in interrogation block 53. It may be mentioned, at this juncture, that, in all the interrogation blocks in fig. 2, the method is continued according to the downward output of the interrogation block in the case of a positive result of the check and according to the lateral output in the case of a negative result.

In interrogation block 53, on the basis of the results of interrogation block 52, a check is made as to whether a shift of the automatic transmission 15 is necessary. If this is so, the corresponding shift is triggered in block 54. The method may even be processed further before the shift in the automatic transmission 15 is concluded. The shift in the automatic transmission 15 is independent of the further processing of the method.

After block 54, block 55 is processed. If no shift is necessary, then block 55 is processed immediately after interrogation block 53. In block 55, by a suitable activation of the clutches and brakes in the automatic transmission 15, the force flux between the prime mover 11 and power divider 20 is interrupted. At the same time, the output torque of the prime mover 11 is reduced independently of the position of the power actuating member 13.

In the following interrogation block 56, in a first step, a check is made as to whether the direction of rotation of the vehicle wheels 35, 40 coincides with the desired direction of rotation which the vehicle driver sets by means of the selector lever 17. In a second step, a check is made as to whether, in the case of a correct direction of rotation, a difference between the current speed and the speed of the commencement of the shift is lower than a limit value.

If one of the interrogations delivers a negative result, then, in block 57, the brake system 45 is activated and consequently a braking torque is built up. In the case of a false direction of rotation of the vehicle wheels 35, 40, the motor vehicle is braked to a standstill, and, if the differential speed is too high, a constant speed difference is set.

After the processing of block 57 or if both interrogations in block 56 deliver a positive result, the shift in the power divider 20 is executed in block 58. After a fixed cycle time of, for example, 10 ms, a check is made in interrogation block 59 as to whether the shift is already concluded. If this is not so, the method jumps back to interrogation block 56. The direction of rotation and the speed are therefore constantly checked during the shift.

When the shift is concluded, in block 60 the force flux in the automatic transmission 15 is restored by the closing of the corresponding clutches. In addition, a torque corresponding to the instruction from the vehicle driver is set again on the prime mover 11. If the brake system 45 has been activated in block 57, the built-up braking torque is at the same time reduced again. The shift is consequently concluded.

The method is terminated in the following block 61.